STUDIES ON ORGANIC SOIL PROFILES III: SOIL DIFFERENTIATION UNDER POPLAR AND WILLOW STANDS IN THE FLEVOPOLDERS

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Summary

Forest plantations in the Flevopolders, reclaimed during the fifties, offer very good possibilities for studies on the relationships between the factors vegetation, parent material and time and the initial soil formation, in particular the development of the organic profile.

Preliminary research was carried out on two poplar stands (Robusta and Balsam), both 27 years old and on similar parent material, and on two natural willow stands, both 17 years old, but on different parent materials (sandy versus clayey). The soils, although very recent, shows marked differences in profile morphology as well as in chemical characteristics. "Robusta soils" and "clayey willow soils" exhibit for example less accumulation of organic matter, stronger nitrification and a higher nutrient status. These phenomena can be ascribed to differences in the rate of mineralisation/humification of the litter.

In case of the willow stands, the differentiation is most probably due to the less favourable soil physical conditions in the sandy soils. The differentiation in the "poplar soils", however, seems to be due to differences in litter characteristics, in particular their edibility.

Keywords: Humus profiles, marine deposits, nutrient cycling, poplar stands, willow stands.

Introduction

East Flevoland has been reclaimed in 1955 and South Flevoland in 1968. It is therefore not surprising that soil development in these polders is still in its infancy: Leaching, weathering and accumulation of organic matter have only just started and soil ripening is often still incomplete.

The Flevopolders are particularly suited for studies on the effects of vegetation, parent material and time on initial soil development, in particular on the development of organic soil horizons. The main reasons for this are that the vegetational history is exactly known and that a large variety of forest plantations and parent materials occurs. Drainage, furthermore, is strongly controlled and antecedent soil formation is completely lacking.

Preliminary investigations on the organic profile development, of which the first results are presented below, have been carried out at two sites: the Bremerbergbos and the Lepelaarsplassen. A more systematic study into the organic profile development of forest soils in the Flevopolders started in summer 1985.

Site characteristics

In the Bremerbergbos soils on similar parent material and with similar drainage, but under different types of poplar plantations (Robusta and

Table 1. Organic matter contents in weight % (upper part) and densities in kg/m^3 (lower part).

Bremerbergbos Poplar Robusta		Balsam		Lepelaarsplassen Willow 1		Willow 2	
L	58.9	L	77.4	L1	79.0	L	84.3
Ah1	10.2	F	50.0	L2	38.7	Ah1	25.5
Ah2	5.0	F+A	22.5	A	5.8	Ah2	9.4
Bw1k	2.1	Bw1	2.3	Bw	5.8	Bw1	9.8
Bw2	4.5	Bw2	2.2			Bw2	8.3
		Bw3	4.1				
L	67	L	37	L1	99	L	32
Ah1	100	F	41	L2	91	Ah1	174
Ah2	1190	F+A	212	A	784	Ah2	167
Bw1k	1310	Bw1	1240	Bw	870	Bw1	n.d.
Bw2	1310	Bw2	1240			Bw2	n.d.
		Bw3	1240				

Balsam), were studied. Both stands are 27 years old. The soils are developed in calcareous silt loams (top soil) to silty clay loams (deeper than 30 cm), overlying coarse sands (see also figure 1). Subsequent on its reclamation, but prior to being planted, the parcels have been used for agriculture for a period of 5 years and at that time have been fertilized (mainly N-fertilizer). In the same period the "balsam parcel" has once been treated with insecticides.

In the Lepelaarsplassen soils under two natural willow stands, about 15 years old, but on different parent materials were studied. The stand "willow 1" is on a thin sludge deposit with a texture of sandy clay loam, overlying deposits with a texture of clay loam. "Willow 2" lacks the sludge deposit and is directly on the clay loam (see also figure 1).

Field observation showed that marked differences exist in profile development, in particular of the organic profile, between the different stands in both Bremerbergbos and Lepelaarsplassen: Balsam poplar and "willow 1" exhibit a stronger accumulation of organic material and a more pronounced horizon differentiation. In each stand a characteristic profile was described and sampled for further analyses.

Analyses and results

In figure 1 the soil horizons of the four profiles analyzed are schematically indicated. The soil horizons are according to the Guidelines for Soil Profile Description (FAO/UNESCO, 1975) and to the system of Klinka et al. (1981).

General data on the soil profiles are presented in figure 1 (carbonate contents and grain size distribution) and in figure 2 (C and N contents, C/N ratios and pH values). Organic matter contents and bulk densities are listed in table 1. Compositions of soil water extracts are presented in table 2 and are expressed in mmol/100 g dry sample. The amounts of water soluble Ca, Mg and K, expressed in mmol/m^2 per cm soil as well as total amounts per soil horizon are presented in figure 3, 4 and 5. In figure 6 values for water soluble NO_3-, NH_4 + and org. N are presented.

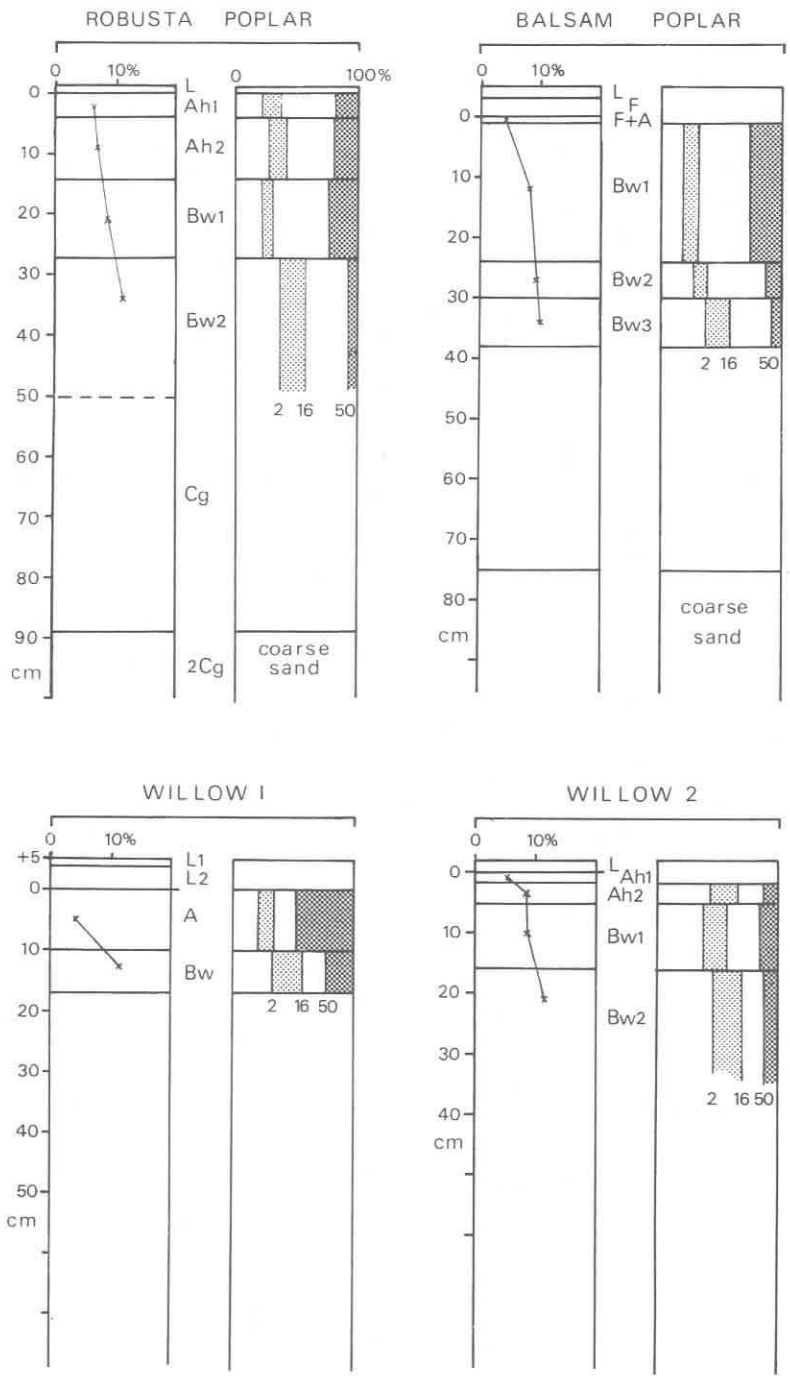

Fig. 1. General data on the soil profiles studied:
Left: Soil horizons and carbonate contents.
Right: Grain size distribution (fractions <2 , 2-16 , 16-50 and >50).

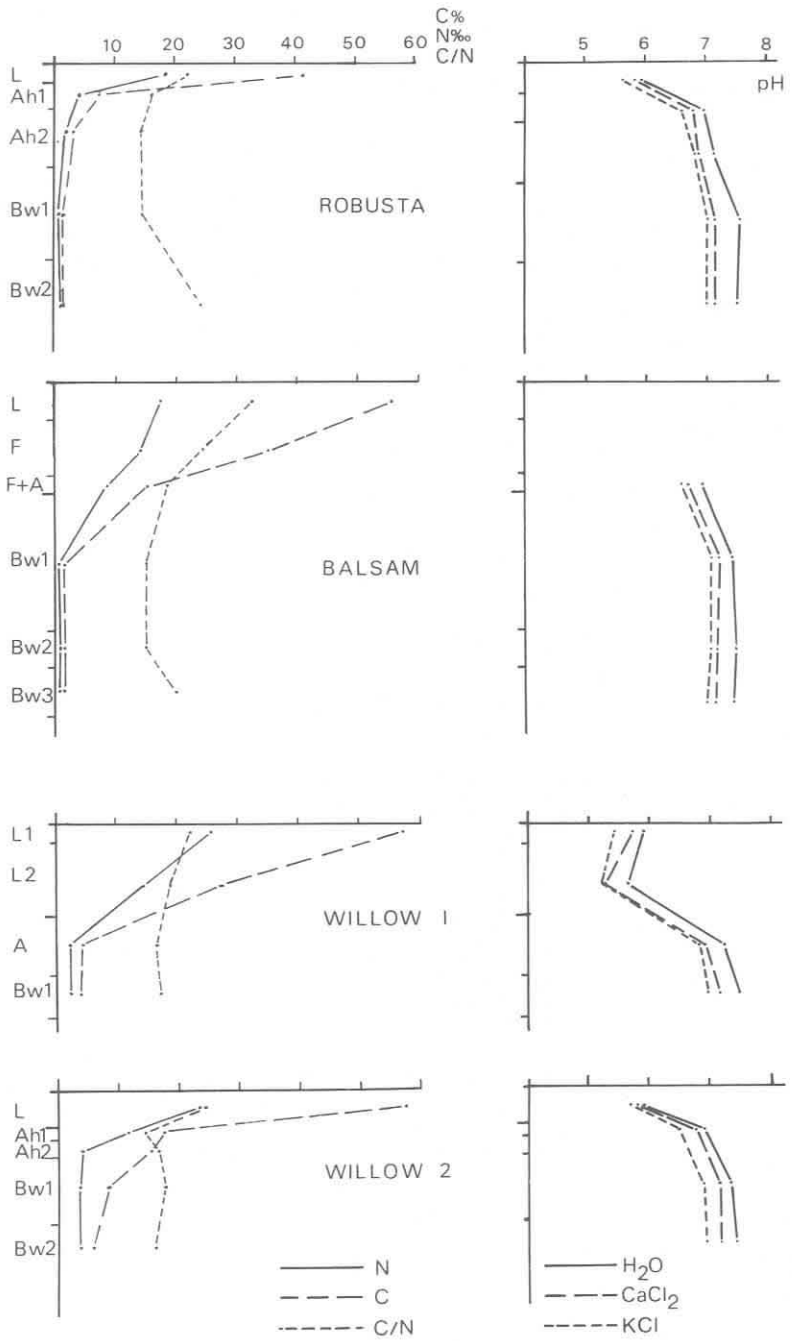

Fig. 2. Chemical data
Left: Total C and N and C/N ratios.
Right: pH values in 1:5 extracts (organic horizons) and 1:2.5 extracts (mineral horizons).

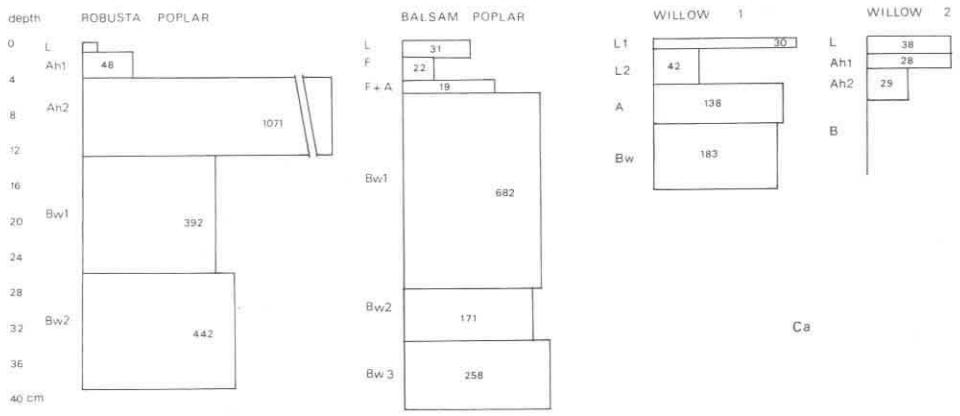

Fig. 3. Water soluble Ca^{2+} expressed in $mmol/m^2$ per cm soil and total amounts in $mmol/m^2$ per soil horizon.

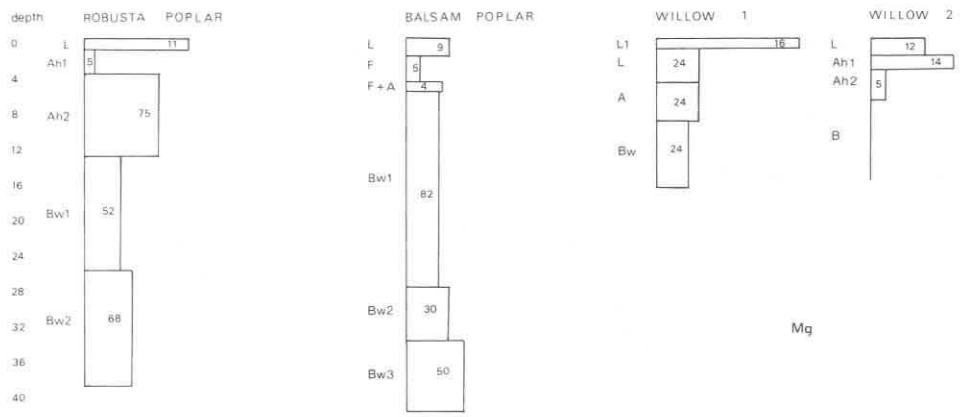

Fig. 4. Water soluble Mg^{2+} expressed in $mmol/m^2$ per cm soil and total amounts in $mmol/m^2$ per soil horizon.

Discussion

The general data confirm the field observations: The soils with stronger developed organic horizons (Balsam and willow 1) indeed exhibit a more pronounced accumulation of C and N and, under poplar, a distinctly higher C/N ratio.

The poplar stands

The Balsam poplars, as compared to the Robusta poplars, exhibit a more vigorous growth. However, although some related differences will exist in biomass input and in elemental composition of the input in the poplar stands, these cannot account for the observed differences. These must primarily be ascribed to differences in the rate of mineralization and humification as well as in the faunal and microbial activities connected with these processes.

Field evidences for a stronger faunal activity under Robusta poplar

are the weak horizon differentiation and well developed fine crumb structure of the Ah horizons , which in the soil under balsam is, respectively, strong and weak coarse angular blocky.

Indications for a more retarded breakdown of litter into humus and a lower level of nutrient cycling under the Balsam poplar are also found in the soil water analyses: Water soluble N, K, Ca and Mg (i.e. kg/m^3) are lower. Furthermore, organic N is the dominant N species and NO_3^- is low, indicating that N-mineralization and nitrification are somewhat retarded. These data also point, for the Robusta poplar, to a massive mineralization and release of nutrients in the Ah2 horizon, which in fact is the main rooting horizon, whereas under the Balsam poplar a much more regular distribution and lower level are observed.

Lower rates of mineralization and humification under the Balsam poplar should lead to stronger accumulation of organic C and N, i.e. to higher total amounts of organic C and N, expressed in kg/m^2. Unfortunately the initial organic matter content of the sediment is relatively high and as a result only a rough estimate of the amount accumulated can be obtained. Taking as a measure all organic matter in the L and Ah1 horizons of the "Robusta profile" and in the L, F and F+A1 horizons of the "Balsam profile", these values are 0,65 kg C and 0.034 kg N per m^2, and about 1.2 kg C and 0.048 kg N per m^2 respectively.

As regards the water soluble P contents, these are clearly controlled by their solubility in calcareous media and thus, except for the organic horizons, are invariably low.

The poplar parcels, prior to being afforested, have been managed in different ways (fertilization and insect control). It is, hoewever, extremely unlikely that these differences in management practices had more than very temporal effects, i.e. only on the very initial organic profile development. The atmospheric input of N over the past 27 years, for example, exceeds by far the amounts added as fertilizer. Furthermore, levels of water soluble phosphate show little variation between the stands, except for organic P content, which is controlled by the characteristics of the organic matter. It is therefore concluded that the differences in preafforestation management played an at most very insignificant role in the genesis of the soils studied. Lastly, in the field no indications

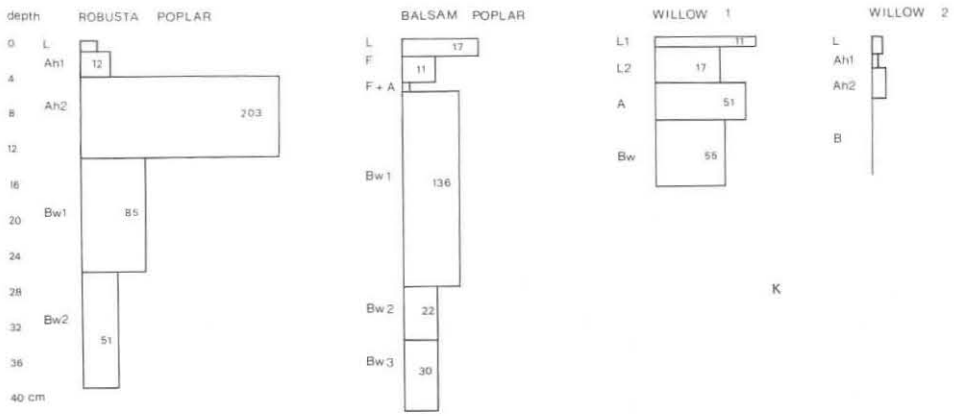

Fig. 5. Water soluble K^+ expressed in $mmol/m^2$ per cm soil and total amounts in $mmol/m^2$ per soil horizon.

were found for differences in soil fauna composition, other than related to differences in soil conditions, earthworms being present at both sites.

Given the constancy of all soil forming factors, but the vegetation, the already quite considerable differences (in 27 years) in humification, mineralization and nutrient cycling can only be ascribed to differences in litter characteristics, in particular in their edibility for the soil fauna. It is not excluded that such lower edibility has to do with the "exotic" origin of the Balsam poplar.

The willow stands

The soils under the willow stands exhibit similar phenomena: C and N accumulation, horizon differentiation and soil structure are closely related to each other and are most expressed in Willow 1. Estimation of

Table 2. Composition of soil water extracts expressed in mmol/100 g dry sample.

Horizon	K	Ca	Mg	NH_4	NO_2 NO_3	org N	ortho P	org P	SO_4	HCO_3
Robusta poplar, Bremerbergbos										
L	0.28	5.48	1.71	5.30	0.00	6.56	1.49	1.17	0.85	6.76
Ah1	0.29	1.21	0.13	0.10	0.31	0.24	0.03	0.03	0.01	1.47
Ah2	0.19	1.00	0.07	0.05	0.08	0.12	0.00	N.D.	0.01	0.10
Bw1	0.05	0.23	0.03	0.00	0.00	0.03	0.00	0.00	0.02	0.42
Bw2	0.03	0.26	0.04	0.00	0.00	0.03	0.00	0.00	0.04	0.48
Balsam poplar, Bremerbergbos										
L	2.30	4.18	1.27	2.29	0.02	3.74	1.40	1.29	0.69	3.51
F	0.91	1.76	0.41	0.76	0.47	0.98	0.21	0.31	0.18	3.51
F+A	0.04	0.97	0.19	0.29	0.17	n.d.	0.02	n.d.	0.04	1.96
Bw1	0.05	0.25	0.03	0.01	0.01	0.06	0.00	0.00	0.01	0.47
Bw2	0.03	0.23	0.04	0.00	0.00	0.03	0.00	0.00	0.03	0.40
Bw3	0.03	0.26	0.05	0.00	0.00	0.04	0.00	0.00	0.05	0.32
Willow 1, Lepelaarsplassen										
L1	1.15	3.02	1.61	3.21	0.81	3.36	1.19	0.50	0.29	5.25
L2	0.81	1.15	0.52	0.60	0.79	1.19	0.38	0.07	0.27	1.38
A	0.13	0.34	0.06	0.01	0.14	0.08	0.00	0.00	0.02	0.57
Bw	0.09	0.30	0.04	0.00	0.10	0.07	0.00	0.00	0.03	0.52
Willow 2, Lepelaarsplassen										
L	0.46	5.88	1.92	8.29	0.07	9.94	2.45	1.27	0.87	6.36
Ah1	0.05	1.09	0.53	0.23	0.00	0.55	0.02	0.06	0.07	2.24
Ah2	0.11	0.50	0.09	0.01	0.18	0.13	0.00	0.00	0.03	0.79
Bw1	0.66	0.44	0.08	0.00	0.15	0.15	0.00	0.00	0.05	0.60
Bw2	0.05	0.52	0.08	0.01	0.13	0.14	0.00	0.01	0.07	0.70

the amount of C and N accumulated leads to the following values: 1.7 kg C and 0.082 kg N per m^2 for the L horizons of "Willow 1" and 0.8 kg C and 0.045 kg N per m^2 for the L + Ah1 horizons of "Willow 2".

The contents of water soluble elements expressed in mmol/m^2 c.q. mmol/m^3 not only depend on mineralization and humification rates but also on texture (for example adsorption by clay) and biomass input and as a consequence are difficult to interprete. The data in table 2, combined with those in the figures 3-6, however, rather clearly indicate that mineralization and nutrient cycling is more prominent in the soil of willow 2, in accordance with tendencies discussed above.

As can be seen in figure 1 strong differences exists in texture of the superficial parent material. Therefore some quantitative differences in biomass production between the two stands is to be expected. The sludge deposits characteristically have very poor physical properties, such as low porosity and low penetrability for soil fauna, which are due to their mode of deposition. It is therefore highly probable that the differences

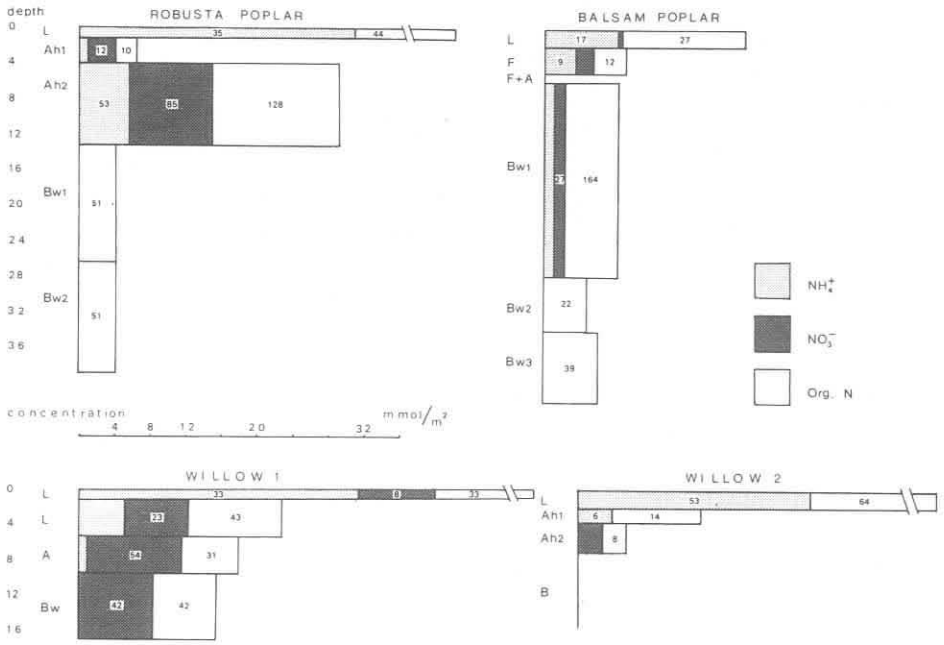

Fig. 6. Water soluble NH_4^+, NO_3^- and organic N expressed in mmol/m^2 per cm soil and total amounts in mmol/m^2 per soil horizon.

in development and characteristics between the two soils are due to the rather adverse conditions for soil fauna in the sludge deposits, rather than to differences in biomass production.

Conclusions

The research showed that within a few decades minor differences in vegetation or parent material may already lead to clear differences in development and nutrient status of soils. Further research should be carried out on the effects of such differentiation on soil genesis and on forest succession and production, and its results could be applied in the management of forest plantations in the polders.

The differentiation is clearly reflected in the organic profiles, as observed in the field. Therefore, field surveys of organic profiles can serve to rapidly establish major trends in soil development and in nutrient cycling.

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